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HOW TO PRICE A BIT

by Kevin Werbach

What should it cost to send a bit of data across the Internet? It sounds like a simple question, but the answer is surprisingly complex. Networks involve a mix of fixed and variable investments, and pricing requires assumptions about demand levels, competition and usage patterns. The entire Internet industry depends on communications networks, but the economics of those networks are poorly understood and likely to change. High-level trends are obvious: Convergence, growing capacity and falling prices. The most interesting phenomena, however, occur locally. Despite the abundance of bandwidth, most users still experience congestion.

A number of companies are working to make the Internet more scalable and more reliable. Through their effects, bandwidth will become a commodity, easily bought and sold in multiple configurations. Companies will be able to prioritize traffic to ensure that critical information gets through, and the Internet will increasingly become a vehicle for delay-intolerant services such as voice and streaming video. Simplicity at the user level, however, will mask growing complexity behind the scenes.

The communications industry has evolved steadily for such a long time that it is hard to imagine discontinuous change. Yet rapid transformation is a very real possibility in the next decade. The outcome will determine whether the Internet can grow into a true mass medium and a universal platform for commercial activity.

The physical, legal and financial underpinnings of the traditional voice network are collapsing (see Appendix, page 21). The cost-plus pricing models of the telecommunications cartels are bound to fall amid the dual onslaught of technology and deregulation. Data, not voice, will be the primary form of traffic, and many suppliers will compete to offer ever-faster connections. Band-X and RateXchange, who have created markets to trade spare capacity, provide a glimpse of this future. =====>

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But the story doesn't end there. The Internet is a complex adaptive system, comprising many interconnected and interdependent parts. To the maximum extent possible, traffic seeks routes where there is capacity, shifting around the globe as night moves west. But without technical and financial structures to facilitate more efficient arrangements, there is always the possibility of overload. To users a network is only as good as its slowest link, and the Internet has many slow links. Congestion will remain a problem for the foreseeable future, but this will also create opportunities for companies such as IPHighway, Orchestream, CLASS Data Systems, InterNAP and SkyCache that provide mechanisms to get around bandwidth bottlenecks.

Prices overall will drop (no surprise there), but they will also evolve and differentiate in unpredictable ways. Declining wholesale costs almost never translate directly to retail price reductions: The price of a call from the UK to the US has fallen 70 percent over the past decade, but trans-Atlantic cable costs on a per-voice channel basis have gone from \$9000 to \$125. What you charge depends heavily on who you are, and where your profit margins come from.

In an earlier issue, we predicted that bandwidth would generally be abundant, but that there would be frequent periods of scarcity (see Release 1.0, 12-95). Indeed, since that time capacity has skyrocketed, but so has demand. This trend shows no sign of abating.

More people will use the Internet two or five or 20 years from now, and those users will also require more bandwidth and devices. First, as higher-bandwidth network-access technologies such as digital subscriber line (DSL) and cable modems become available to the residential mass market, individual users will place greater demands on the network. Ten thousand users with one-megabit-per-second (mbps) connections could require 10 gigabits per second (gbps) of total capacity if everyone were online simultaneously, far more than any Internet backbone provides today. The exponential scaling of demand poses a far greater challenge than the arithmetic growth of users. Second, applications such as streaming video will become viable for the mass market, further bumping up capacity requirements. Finally, as networks evolve from dial-up connections to "always-on" data-oriented environments, applications will increasingly use capacity even when users are not present. Computer-to-computer traffic will drive demand, with more and more devices becoming Internet-enabled. As UUNET chief scientist Mike O'Dell points out, "The fundamental error people make is believing that humans have something to do with this."

The year of convergence: 1984-2002

Analysts have proclaimed the imminent arrival of convergence for two decades. Everyone agrees that separate voice, video and data networks will soon be replaced by... something. Yet the definitions of convergence have somehow never seemed to converge. The telephone network engineers thought they would lead the way to nirvana with the Integrated Services Digital Network (ISDN), or Asynchronous Transfer Mode (ATM) switching, or perhaps video dialtone. The cable companies rhapsodized about "full-service networks" using their broadband connections to enable the killer apps of home banking and video-on-demand. Internet experts knew that push media and WebTV would soon sweep the world. Governments figured that removing legal

barriers would generate rampant cross-media competition, with multiple broadband wires sprouting affordably into every home.

It hasn't happened that way. At least, not yet. Convergence is real, but it's not nearly as simple as everyone thought. The Internet today still depends heavily on the economics and regulatory dynamics of the old voice telephone network (see Appendix, page 21). The nagging problem is that network operators desire a return on their investments. The necessary infrastructure costs real money, and the return on investment has always been somewhat speculative. Companies with lucrative franchises have little incentive to cannibalize their own revenue streams absent a serious competitive threat. The result is a sort of prisoner's dilemma. None of the companies best able to make convergence happen feels the need to act absent a competitive threat from one of the others.

Con-vergence, not mono-vergence

The crucial point is that convergence means heterogeneity rather than homogeneity. True, one network can now carry multiple kinds of traffic. Such networks, however, will often be more complicated than networks optimized for a single function. Each kind of traffic has particular usage patterns, cost elasticities and alternative media. Broadband data networks are not deployed in a vacuum; they must interconnect with legacy infrastructure and regulatory environments. Service providers will have a harder time guaranteeing quality of service when traffic must traverse multiple networks, using different technologies and equipment from many different suppliers (see page 6). The Internet's distributed, layered architecture facilitates rapid innovation at the edge of the network, but also leads to greater intricacy. This complexity will only increase as peering, which let traffic shift around easily, is replaced by settlements that provide economic incentives for allocating idle bandwidth (see page 10).

Change in complex systems tends to be discontinuous, in what biologists call "punctuated equilibrium." An environment may appear stable for long periods of time, but shift rapidly once a tipping point is reached. The traditional telecommunications industry, which generated \$220 billion in service revenue for US carriers and \$739 billion worldwide in 1996, is entering a period of profound uncertainty. Data bandwidth will exceed voice by the end of this year, and will represent over 90 percent of global traffic in less than a decade, according to researchers Philip Mutooni and David Tennenhouse. Over many routes data already predominates; voice capacity between Sweden and the US, for example, is approximately 50 mbps, but Internet capacity exceeds 800 mbps.

Despite all this, voice still represents the vast majority of telecommunications revenue. The over-\$100 billion US long-distance market alone dwarfs the \$9 billion in Internet access revenues in 1997. Voice prices today are arbitrary because of the influence of regulators and the absence of competition (see Appendix, pages 22-25). Per-minute pricing for local calls is anathema for most Americans, yet it is the standard in most of the world over the same kinds of networks. Even within the US, prices vary wildly from state to state, independent of geographic cost differences. As unregulated data services represent a greater and greater share of usage, however, something is bound to shift.

SCARCITY OR ABUNDANCE?

Several technical breakthroughs including wave-division multiplexing (WDM), which multiplies available capacity over fiber-optic networks using multiple frequencies of light, have greatly reduced transmission costs. "New" telcos such as Qwest, Level 3 and Williams Communications have all announced plans to build massive fiber backbones across the US, and several companies are deploying large networks across Europe and Asia. Submarine cables including Project Oxygen (see page 5) promise to multiply international capacity many-fold. Low-earth-orbiting satellite systems such as Teledesic (see Release 1.0, 2-95) plan to offer global high-speed connections by 2003. To support these networks, a new crop of start-ups such as Pluris, Avici and Juniper plan to build routers capable of handling over a terabit per second (tbps). Industry observer David Isenberg, who recently went independent after 12 years at AT&T Bell Labs, says that the combination of new capacity and new entrants uncommitted to the status quo means that "all the ingredients of an unstable market appear to be there."

It's all about tradeoffs

Economics is the study of choice under scarcity. Without scarcity, individuals need not weigh costs and make tradeoffs. Whenever capacity is cheap, providers will simply throw bandwidth at their problems. Qwest can provide high-quality Internet telephony because its massive and so-far uncrowded network can transmit packetized voice in uncompressed 64 kilobits-per-second (kbps) streams without breaking a sweat. When bandwidth is scarce, companies will develop clever techniques to save it, just as hard-disk compression software became wildly popular for a short period when drive capacity fell behind software size.

Drilling deeper, communications prices reflect the balance of transmission, switching and storage costs. Each factor can to some extent substitute for the others if it is cheap enough on a relative basis. With enough bandwidth, it wouldn't even make sense to route each user's data to separate endpoints. Rather, much like radio, everyone's information would be broadcast throughout the network, and users would "tune" into their own encrypted datastream. (This is the architecture of "passive optical networks" that use WDM over fiber connected directly to customers' homes.)

The falling price of bandwidth will shift the economics of the Internet well before that point. From a business standpoint, abundant bandwidth gives power to those vendors, mostly on the edge of the network, who offer value-added services. What Isenberg calls the "stupid network" arose because in an inter-networked environment many cheap computers can do a better job than the huge central switches of the telephone network. Carriers will no longer be able to control pricing and application functionality simply because they are responsible for moving bits.

With skyrocketing demand, however, the balance has shifted. Following Moore's law, semiconductor performance has indeed doubled every 18 months, but bandwidth requirements on Internet backbones have doubled every four months. As a result, service providers have added more processing and complexity to the network to manage capacity better. Caching, private inter-connection points and policy-based routing (see pages 7-13) are all attempts to save scarce bandwidth. The amount of money pouring into new

backbone networks suggests that many investors believe a bandwidth glut is unlikely. But the current equilibrium is unstable. Technological or competitive developments in one area will change the dynamics, creating new market opportunities until the system returns to temporary balance.

Project Oxygen

Seventy percent of the Earth's surface is water, and sending bits across oceans is difficult. Satellites suffer from relatively limited capacity and high latency (response time). Submarine cables are the other alternative. Carriers have invested some \$15 billion dollars laying ever-bigger cables over the past decade. Because each cable costs hundreds of millions of dollars and takes years to build, cartels have traditionally split the cost and pre-allocated capacity through 25-year leases.

New Jersey-based CTR Group has audacious plans to change all that. Project Oxygen will be a global "super-Internet" of submarine cables around the globe, with major segments operational by the year 2000. By 2002, CTR Group expects to spend \$8 billion to deploy 158,000 kilometers of cable connecting 101 landing points in 74 countries. Founder Neil Tagare wrote the feasibility study for the \$2 billion Fiber Optic Link Around the Globe (FLAG), which greatly increased submarine cable capacity between Europe and Asia. FLAG was the first privately-funded cable system; Project Oxygen pushes the model much further.

Rather than doling out point-to-point capacity, Project Oxygen will make international bandwidth available to carriers and companies on demand. A customer will simply purchase a given level of capacity and shift it to any segment of the network it desires.

According to Tagare, "The one thing every phone company has in common is that they are always wrong in their forecasts." Some 50 percent of carrier investments in international capacity are unnecessary, because demand patterns do not follow long-term projections. The growth of the Internet has worsened this problem, because Internet traffic grows considerably faster and more unpredictably than voice. In effect, Project Oxygen's network model will average out the risk of misjudging capacity needs on any route, creating a more predictable market for carriers. If a particular link on Project Oxygen does become congested, traffic can be sent over alternate routes until more capacity is added.

The most impressive aspect of Project Oxygen is the sheer volume of bandwidth it will provide. Minimum capacity will be 160 gbps on each fiber pair and 640 gbps on each cable segment. By comparison, total trans-Atlantic capacity in December 1995 was 36 gbps, and trans-Pacific capacity was 9 gbps for submarine cables and satellites combined. Project Oxygen's pricing will also dramatically undercut current rates. CTR Group is taking orders for capacity now, with prices on a sliding scale based on volume, and expects to close its first round of financing commitments by December.

SCALING AND QUALITY OF SERVICE

The fundamental challenge for the Internet is scaling. Both demand and supply will continue to grow, and approaches that once worked may break down as the numbers get bigger. Companies must understand networks holistically, and they must find ways around bottlenecks that do not become bottlenecks themselves. In a heterogeneous environment there can be no magical accelerator pedal. There are, however, a number of second-best solutions to make more efficient use of the bandwidth we have.

Not all bits are created equal. You might not mind if your e-mail message arrives a minute late, but if one second of your real-time voice conversation gets delayed you may never get it back. Similarly, a business that has invested large sums into its electronic-commerce Website will be more concerned about reliable connections than a residential user with a personal home page. Quality of service (QOS) management seeks to match network performance with a particular user's expectations, at a price.

The Internet was designed as a "best-effort" network. There is no guarantee that any given packet will reach its destination; packets not arriving are simply re-sent. This system avoids the administrative overhead of the public switched telephone network, but also limits the utility of the Internet for mission-critical applications. Even when companies are willing to pay more for enhanced QOS, they often cannot get it today. The greatest barrier is that any single Internet transmission usually passes through multiple networks. Even if the originating service provider deploys sufficient bandwidth and can guarantee robust QOS, the user gains no benefits if the other providers in the chain don't do so too. QOS is easier to manage inside private networks, but even there information usually must traverse multiple devices and wide-area network (WAN) links.

On the road to a more reliable Internet

A small category of users are big enough to create QOS on their own. For example, the major players in the US automotive industry plan to launch a massive private network later this year to provide high-quality connections to their thousands of trading partners. The industry believes that, by developing a single network standardized on the Internet protocol (IP), it can dramatically reduce costs compared to current proprietary electronic data interchange connections. The Automotive Network Exchange is being developed in conjunction with Bellcore, which will require participating Internet service providers (ISPs) and exchange points to meet certification requirements in eight categories: Network service features, interoperability, performance, reliability, disaster recovery, security, customer care and trouble handling.

QOS doesn't eliminate the need for more bandwidth; it simply makes it possible for some users to get more reliable service. Most Internet traffic will still use "coach class," so ISPs will have to provision sufficient capacity for the baseline service to remain acceptable.

A few years ago, ATM and the Internet Engineering Task Force's (IETF's) resource reservation setup protocol (RSVP) were expected to solve QOS con-

cerns. Both have their place, but neither has proven to be a magic bullet. ATM, which emerged from the telephone network world, is a switching protocol with sophisticated QOS management features. But this functionality comes at the price of significant complexity and overhead. Most companies have chosen Ethernet instead of ATM for their local-area networks, and are unwilling to replace their existing hardware. RSVP allows applications to request that sufficient bandwidth be reserved for particular traffic flows. To take advantage of RSVP, however, all routers and applications in a network must be upgraded. Both ATM and RSVP also manage QOS on a per-flow basis, a technique that doesn't scale well enough for the core of the Internet. As a result, work in the IETF has shifted toward a simplified approach known as Differentiated Services (Diff Serv).

More than a dozen companies are developing QOS solutions of one form or another, and all the major router vendors have incorporated QOS features into their products. The biggest problem has been supporting QOS on an end-to-end basis in today's networks. Few network managers have taken advantage of the QOS features in routers and switches because of the complexity of configuring multiple devices, and getting their counterparts to do so. What is needed is a business-oriented abstraction layer that hides the complexity of the process.

New products forthcoming from start-ups IPHighway, Orchestream and CLASS Data Systems (acquired by Cisco in early May) promise to achieve this goal. All three propose software-based management systems to configure QOS across entire networks. With any of the three products, a network administrator can use a simple graphical user interface to set policies for specific users, applications, times, etc. For example, an investment bank might want urgent trades to receive higher priority across a WAN than packets associated with large streaming videos.

All three technologies work both within corporate networks and across WANs operated by ISPs. From a business-model perspective, however, Orchestream is focused primarily on selling licenses to service providers and reaching companies on a resale basis, while the other two companies intend to market to both kinds of customers. Both IPHighway and Orchestream also plan to offer inter-provider modules that will allow ISPs to exchange QOS requests and billing information, paving the way for more sophisticated settlement agreements between providers (see pages 10-12).

All three companies profess to be agnostic as to QOS technology, rather than requiring networks to be upgraded to support RSVP or some other standard. The challenge for all of them is create solutions that work in existing heterogeneous networks, even though open standards are not yet available for all the necessary functions. The companies are working with the IETF on standards that will enhance the functionality of their offerings, but in the interim they offer proprietary solutions.

Orchestream and CLASS Data Systems both hope to leverage the dominance of Cisco routers in IP networks, the latter by becoming part of Cisco. Many Cisco interfaces are open, however, and these systems must all support devices from multiple vendors, so CLASS Data Systems' new identity by no means locks out the competing products. IP Highway is more ambitious about inserting its policy servers as an addition to existing infrastructure, although it claims to be completely transparent to the network.

As the three companies bring products to market, their approaches seem to be converging. Real-world customers will provide the acid test, although the potential market is big enough to accommodate multiple players.

IPHighway

Shai Herzog began working on Internet quality of service issues four years ago while a graduate student at the University of Southern California, and later was the co-author and driving force behind RSVP. Last summer he and David Zvilichovsky co-founded IPHighway to develop end-to-end QOS management systems. IPHighway is backed by the BRM Group, which funded Check Point and BackWeb; former Bay Networks ceo Andy Ludwick is also an investor and board member. The 25-person company, with an engineering team in Jerusalem and corporate offices in the US, plans to release its first products in the fourth quarter of 1998. It is currently in testing with a small number of customers. Pricing will depend on network size and components purchased, with a basic package costing around \$27,000.

Herzog acknowledges that RSVP works well for some applications but doesn't scale well across large WANs. He says IPHighway will support RSVP and other QOS technologies such as IP Precedence and Diff Serv equally. IPHighway's software is designed make end-to-end QOS easy to manage on any network, including corporate intranets, VPNs and large ISPs.

Using IPHighway's three software modules, managers can define network-wide QOS policies without having to configure individual routers. The Management Server works with directories to maintain a central database of QOS information, and provides a graphical user interface for managers to define policy rules. The Management Server can also detect traffic subject to QOS agreements, and issue RSVP requests for those applications that do not support RSVP. Policy servers, each of which can control several devices, authorize and arbitrate between QOS requests based on those rules. Finally, QOS Generators monitor traffic at the edge of the network and can automatically create QOS requests as needed.

IPHighway is pushing for adoption of the IETF's Common Open Policy Service (COPS), which Herzog helped design. COPS will provide a standard mechanism for individual switches and routers to outsource their policy decisions to policy servers. Cisco and 3Com have announced support, but the protocol isn't expected to be ratified until the end of this year. In the absence of COPS, the policy servers must issue bandwidth reservation requests without knowing the load on each router.

IPHighway's technology and other QOS tools will make it possible to differentiate prices among customer segments, and will make it easier to deploy services such as Internet telephony that require low latency.

Orchestream

Orchestream's provisioning system automatically configures the QOS features in existing Cisco routers. (Disclosure: Esther Dyson is an investor in Orchestream.) The 30-employee UK-based company was founded in February 1996, although its development team was not in place until April 1997. Orchestream's system is now in field trials and will be launched commercially to a select number of customers at the end of June. CEO Charles Muirhead

claims Orchestream/Provider is much less heavily tied to RSVP than other approaches, because it can translate QOS requests into existing router management interfaces such as Cisco's Command Line Interface. This, he believes, gives the company an advantage in real-world networks, few of which support RSVP today.

Orchestream/Provider offers a simple, central interface for network managers to assign QOS levels to users. It then automatically configures the routers those managers control. The software-based system uses a combination of database technology and the lightweight directory access protocol (LDAP) to track service policies necessary to allocate bandwidth to different users. Managers use a graphical user interface to define policy objects, which are then sent out to local policy servers as needed.

The system can either "push" policies to traditional routers or can respond to policy requests from routers enabled with COPS. Next-generation routers may incorporate the Orchestream policy agent directly, eliminating the need for a trip across the network to assign QOS to a traffic flow. For scalability, Orchestream is heavily focused on doing per-flow control only at the edge of the network, and aggregating QOS requirements towards the core using Diff Serv.

According to Muirhead, "Today the Internet is like the airline industry with only economy seats and no ability to adjust the number of flights per week!" Orchestream's system allows companies to save on costly WAN bandwidth, and also makes new applications such as high-quality Internet telephony easier to implement. From the service-provider standpoint, Orchestream allows ISPs to differentiate themselves in an increasingly-crowded market.

Orchestream plans to focus on service providers because they already manage most WANs, and because Orchestream believes QOS must start at the core of the network before moving to the edge. The company is currently in negotiations with several major ISPs and carriers, and is also in talks with major network equipment vendors.

CLASS Data Systems

Like Orchestream and IPHighway, CLASS Data Systems enables end-to-end QOS through distributed software connected to a central management server. (Also similar to IPHighway, company executives are based in the US but the engineering team is in Israel). The primary difference is that the CLASSifier system includes intelligent QOS software "agents" that interact with application servers, in addition to network devices such as routers. The agent software can be installed directly on Windows-based servers, or can run on proxy servers that interface with mainframes and other platforms.

The currently-available "Agent-Based Application QOS" classifies traffic at the client-server source, either by network-level parameters such as IP address or by application-specific parameters such as application name, URL and file name. Although users must install additional software, agents allow tighter integration into server applications. For example, different transaction types on an Oracle database could receive separate classifications. CLASS Data Systems vice president of engineering Gilad Zlotkin claims that competing approaches can differentiate only between applica-

tions, not on a more specific basis. Once agents classify traffic flows, they query policy servers for applicable QOS policies, and then request the required service levels from network devices. The system supports both RSVP and priority bit QOS standards.

In May, CLASS Data Systems announced a "Policy to Device Control" option which will be available in the third quarter. Companies can deploy the new product as either an alternative or a supplement to the agent-based solution, depending on their specific network configuration. Policy to Device Control implements QOS policies directly on network devices, similar to the IPHighway and Orchestream approaches.

On May 4, Cisco agreed to acquire privately-held CLASS Data Systems for \$50 million. The acquisition gives Cisco an end-to-end, easy-to-use QOS solution to complement the QOS functionality in its routers. Although unwilling to discuss specific plans, Zlotkin says that "Cisco bought us for what we have and also for what we plan to have." As part of Cisco, CLASS Data Systems will be able to integrate its software more closely with the features in Cisco devices.

INTERCONNECTION AND PEERING

The Internet is, by definition, a network of networks. Some networks are operated by ISPs, while others are run by corporations. Some networks provide connectivity to end users, while others carry traffic between end-user networks. However, just as light behaves as both a particle and a wave, the Internet appears to be both flat and hierarchical. What seems to be a private end-user access network can also function as a transit network. The problem for traffic management is that the Internet has many edges but no center. Traffic is routed dynamically, based on a combination of algorithms and business relationships among multiple providers.

Historically, today's Internet evolved from the NSFNET, a US-government funded research and educational network. The NSFNET backbone carried traffic between regional research networks across the US and elsewhere. Over time, corporations involved in research projects began to hook up their networks to the NSFNET, still operating nominally under a non-commercial "acceptable use" policy. Eventually commercial IP networks emerged, beginning with the spinout of PSINet from NYSErNet, the New York regional network. Finally, the US government phased out its control of the NSFNET, completely turning over backbone functions to private entities by 1995. As part of the transition, the National Science Foundation funded the creation of several public network access points (NAPs), and directed backbone providers to exchange traffic for free at those points (an arrangement known as peering). Privately-funded multilateral exchange points also emerged around the same time, in particular MFS Communications' metropolitan area ethernet (MAEs).

In the three years since NSFNET privatization, the number of backbone providers has increased dramatically. Boardwatch magazine counts over 30 US national providers in its survey. The reality, however, is that a handful of those providers — UUNET, MCI, Sprint, GTE (BBN), PSINet, and AGIS — control the vast majority of routes, and the first three on that list carry some three-quarters of Internet traffic. Peering only makes sense for pro-

viders of roughly equal size; a small network gets much greater benefit from the ability to reach subscribers on a bigger network (see Release 1.0, 12-95). There is, however, no bright line between "Tier 1" providers entitled to peering and "downstream" ISPs that must pay those providers to transit their traffic. The value of peering for two parties depends on more than simply their relative numbers of customers, and the administrative costs of alternative arrangements must be factored in.

UUNET generated a great deal of controversy last year when it revoked peering agreements with several smaller networks and demanded that they pay for their connections as transit customers. UUNET may have gained the most notoriety, but all the large backbone providers are increasingly unwilling to enter into new peering agreements. Major carriers (but less-prominent Internet players) such as GTE and AT&T have found themselves unable to peer with the major backbones, until they purchased existing providers (BBN and CERFNet, respectively) that had peering arrangements in place. The Tier 1 backbones have also negotiated bilateral private peering arrangements with each other, decreasing the amount of traffic they send through the multilateral public exchange points.

What's really at stake here

Whether the Tier 1 providers' refusal to peer constitutes anti-competitive activity is an important question. We certainly think companies' peering policies should be out in the open, rather than subject to non-disclosure agreements as they usually are today. The backbone market has evolved outside the framework of telecommunications regulation, and so far the FCC has stayed out of peering disputes. The proposed merger of MCI and WorldCom has, however, brought greater attention to the competitive dynamics of this area. WorldCom has in recent years purchased the networks of UUNET, ANS and CompuServe, all major backbone players. Its combination with MCI would have made it by far the largest backbone (carrying end-to-end traffic for 62 of the top 100 Internet sites). American and European antitrust regulators raised questions about the competitive effects of the deal, and WorldCom agreed to sell MCI's backbone operations to Cable and Wireless for \$625 million. As we go to press, however, the European Commission's top antitrust official, Karel van Miert, has said the sale doesn't go far enough, so we'll see how all this plays out....

Beyond the competitive issues, public exchange points are becoming a significant performance bottleneck. As usage levels grow, these multilateral connections are increasingly congested. Moreover, as private peering becomes more prevalent, large players find fewer benefits to interconnecting at NAPs and MAEs. Companies increasingly engage in "hot potato" routing, handing off traffic to other backbones at the first possible opportunity regardless of the potential routing inefficiencies. The problem is that there is no organized system of interconnection pricing, leading to confusion and inefficient arrangements. Everyone recognizes the need for more economic and efficient traffic exchange mechanisms, but it is hard for any one provider to put them into place.

Enter the peering brokers. Savvis was the first company to build an Internet backbone out of private connections with Tier 1 providers, completely bypassing the NAPs. Savvis turned heads when it topped a Boardwatch backbone performance survey. Mike Gaddis of Savvis has now formed the Brokered

Private Peering Group (BPPG) to expand the use of private peering. The group's goal is make private peering more economical for smaller backbones, replacing the overburdened NAPs with negotiated connections to private ATM-based interconnection points. The BPPG architecture divides bandwidth among connected ISPs, but once packets leave the interconnection point they may still end up passing through an overburdened public exchange.

InterNAP

InterNAP, a 30-person company based in Seattle, believes its architecture provides a better answer. According to CEO Anthony Naughtin, the problem today is that most major Internet backbones are run by carriers. Original backbone operators such as ANS, Netcom, BBN and UUNET have sold out to facilities-based carriers in order to gain control over their transport costs. However, such facilities-based thinking doesn't help when traffic must be routed across multiple backbones. The performance bottlenecks on the Internet today reside at the exchange points.

InterNAP does not operate any long-haul backbone facilities, nor does it request free peering. Instead, it pays the eight largest backbones for connections into its own private network access points (PNAPs). To these backbones, which collectively represent over 90 percent of Internet routes, InterNAP appears as a typical transit customer. In reality, however, virtually all the traffic InterNAP sends to a Tier 1 backbone is destined for customers on that network.

InterNAP's proprietary route management system, Assimilator, works in conjunction with routers to optimize traffic flows. Today packets may travel across the country or the world to reach a public network access point even though their eventual destination is in the same neighborhood. If a packet comes into a PNAP from the MCI backbone destined for a customer on AGIS, InterNAP will route the traffic directly over its private connection to AGIS. A PNAP, however, is a true multilateral exchange point: InterNAP advertises all of its routes to parties on both side. The result is greatly improved performance for InterNAP's ISP and corporate customers. PNAPs are now operational in Seattle and New York, with San Francisco, Washington, DC, and Los Angeles scheduled to open later this year.

Naughtin, who spent four years at regional ISP NorthwestNet, says InterNAP has so far gotten good cooperation from the upstream providers, because the company pays for its connections and "we are destined to become their largest customer." InterNAP effectively provides the technical and financial infrastructure for more efficient routing that no one backbone provider can offer itself. Naughtin thinks InterNAP's architecture overcomes some of the key barriers to QOS and VPNs over the public Internet. With funding from Hambrecht & Quist, Vulcan Ventures and others, the company plans some 30 PNAPs by the year 2000, a quarter of them outside North America. The company has over 60 large customers including Adobe, Amazon.com, Datek Online, Go2net, Microsoft and Nordstrom.

SkyCache: Caching the caches

Caching is another important component of efficient Internet bandwidth utilization. Caches trade scarce bandwidth for more plentiful storage and processing, allowing frequently-used documents to be downloaded locally

rather than from remote sites. The higher the "hit rate" on the cache, the more bandwidth saved. Several companies now offer caching appliances that ISPs and companies can deploy in their networks, either on a standalone basis or in conjunction with other functions (such as the Bess filtering service, see Release 1.0, 5-98).

Caching solves some of the Internet's scaling problems, but caches themselves face scaling challenges. As the level of users and traffic increases, the cache itself can become a bottleneck. It becomes harder and harder for the cache to maintain copies of the pages users are likely to request. Hierarchical caching provides a partial solution, using multiple caches to aggregate user patterns and thereby store a larger percentage of frequently-viewed files. But simply plugging multiple caches into each other creates its own set of scalability problems. As more data must be passed between local and central caches, the system runs into the same Internet transmission bottlenecks that created a demand for caching in the first place. Newly-public Inktomi, better known as the search engine technology supplier for Hotbot and soon Yahoo!, is bringing its clustering technology to bear on this challenge, using multiple machines in parallel to improve speed and reliability. The real problem, however, involves the transmission links rather than the caches themselves.

SkyCache's answer is to use satellites to enhance cache functionality. Satellites are ideal because they can broadcast large amounts of one-way data over large areas to multiple receivers, without using congested terrestrial links. SkyCache founder Doug Humphrey built Digex into a major regional ISP before selling it to Intermedia Communications. His new 20-person company, based in Laurel, Maryland, will sell a turnkey system for \$2,500 per month to ISPs that includes a satellite receiver and a local caching server. The local caches automatically provide statistics to the "master cache" at SkyCache headquarters, where patent-pending Reactive Caching technology identifies frequently-requested files that are not cached. Those files are then broadcast to all the participating caches through a continuous 4 mbps satellite datastream. The traditional way to increase cache hit rates is to pre-load popular pages, but pre-loading doesn't work when usage patterns shift. Reactive Caching solves that problem. During beta testing Apple's iMac announcement suddenly generated heavy traffic on the Apple Website, and SkyCache automatically updated caches with those pages.

The SkyCache system will interface with any existing cache compatible with the Internet Caching Protocol, an IETF standard for inter-cache communication. SkyCache director of marketing Doug Mohny says the company sees itself as an enhancement rather than a competitor to caching solutions from companies such as Inktomi, CacheFlow and Network Appliance, because it enables users to increase their cache hit rates or link up multiple caches at the edges of their networks. Another benefit of SkyCache is that its architecture fits perfectly with streaming audio and video services, which promise to grow greatly in popularity in the near future. SkyCache bypasses congested Internet exchange points that limit the performance of streaming media, and satellites are perfect for one-way broadcast content.

SkyCache is currently transitioning from beta testing to commercial deployment, and recently closed a \$6-million round of venture funding. Competition is on the horizon. InterCache, also based in Maryland, plans to

launch a similar system based on technology it developed for the military. In Europe, SatinNet has been delivering Usenet news to ISPs via satellite for two years. The company is working to develop satellite cache pre-loading in conjunction with Mirror Image, which places centralized caches at Internet exchange points (See Release 1.0, 3-98. Disclosure: Esther Dyson is an investor in Mirror Image). Cable modem providers are also exploring satellite distribution to supplement caches, although these companies are likely to self-provision because of their access to cable operators' satellite transponder time.

DNS = Delays in Network Speed?

Bandwidth is only one factor in Internet delays. A Bellcore study found that network transmission represents only 42 percent of the time it takes to retrieve a Web page. According to Bellcore's Christian Huitema, the remainder is divided into page preparation at the originating server (33 percent), connection to the remote server (12 percent) and most surprisingly the domain name system (DNS) query (13 percent).

The DNS, which maps mnemonic addresses such as edventure.com onto IP numbers used for routing, tends to be taken for granted. Yet as the study demonstrates, DNS resolution represents a significant Internet performance bottleneck. Bellcore also found that 4 percent of DNS queries simply fail and must be resent (up from 3 percent last year), and that DNS queries represented roughly a quarter of all packet traffic on the Internet (and 10 percent of the bandwidth usage).

There is no easy way to replace every ISP's DNS server with something better. Debates about DNS governance and the creation of new generic top level domains to complement .com, .net and .org may provide an opportunity to enhance the technical underpinnings of the system. Or perhaps DNS will simply lose out in the marketplace to Centraal's Real Name service or Netscape's forthcoming Smart Browser function.

THE RESURRECTION OF DISTANCE?

Conventional wisdom holds that the Internet represents the "death of distance" (also the title of an excellent book by Frances Cairncross of the Economist). The Internet does not require dedicated connections between physical points, so in theory it costs almost the same to send data anywhere. Once carriers deploy fiber-optic networks, the cost and delay to transmit information several thousand miles is virtually the same as to send it across a neighborhood. According to the Organization for Economic Coordination and Development (OECD), the least expensive domestic rate to call anywhere in the US (MCI's five-cents-per-minute charge on Sundays) is now only three-tenths of a cent greater than the average peak rate for a local call in Europe.

However, bandwidth supply has not outstripped demand growth, especially at choke points such as international circuits. Connectivity is much better in North America than the rest of the world. Ironically, London-based Band-X (see page 17) found that locating its bandwidth exchange Web server

in Canada provided better performance (and much cheaper hosting rates) than in England. It still costs money to deploy capacity, and it costs more money to build bigger networks. As long as demand growth continues to require new infrastructure, distance may be a factor in bandwidth cost.

Distance will not, however, necessarily correlate perfectly with geography. In a recent study, the OECD found that the round trip time on an Internet connection from Singapore was 382 milliseconds to North America, 97 milliseconds to Europe, but 885 milliseconds to other countries in the Asia/Pacific region, reflecting differences in infrastructure deployment.¹ In the future, factors such as location and time of day may influence pricing, but in surprising ways.

Digital Island

Internet congestion creates a dilemma for multi-national corporations. Digital Island's answer is to connect directly over leased lines to ISPs in different countries. According to CEO Ron Higgins, the company's Internet backbone is designed specifically for global application deployment, rather than for access services. It uses ATM switches at the core and routers only at the edge of the network, in order to minimize the number of hops packets must traverse. The company also offers value-added services to make it easier for customers to deploy and localize global applications.

Digital Island located its headquarters and its primary data center in Hawaii, twice as close to Asia as the continental US but still subject to American law and pricing policies. To provide global connectivity and "one-stop shopping" for customers, the company has subsequently opened centers in London, New York and Santa Clara. Digital Island has more than 50 major customers, including Autodesk, National Semiconductor and Cisco.

How high can you go?

As commercial ISPs emerged in the US in the mid-1990s, they converged around a price point of \$19.95 per month for unlimited dial-up connections. During the last year, many large ISPs have moved away from this pricing structure, by raising the monthly fee (AOL), capping monthly usage (IBM, AT&T WorldNet) or both (Netcom, Pacific Bell). AT&T reported that some 4 percent of its customers were generating half of the total usage time, because of the long periods they remained online. So far, AOL and AT&T report no drop in subscribership as a result of the changes. But just how much are users willing to pay, especially when new options such as DSL access are made available?

A project at the University of California at Berkeley may help answer this question. The Internet Demand Experiment (INDEX), with \$1.3 million from the National Science Foundation, Cisco and Pacific Bell, is testing user responses to different pricing models. The project will recruit 150 stu-

¹ **Internet Traffic Exchange: Developments and Policy** (OECD 1998), available online at www.oecd.org/dsti/sti/it/cm/prod/traffic.htm.

dents, faculty and staff to connect to the university Ethernet over ISDN connections (DSL when available). Users can adjust connection speeds in real-time up to 128 kbps, but prices increase with speed. Using home-grown billing software, researchers will test several pricing models, including per-minute, per-byte, burst (an occasional maximum speed) and user-selected from among several options.

Berkeley professor Hal Varian points out that whatever pricing model service providers choose, applications will evolve around it (for example, using automated pre-fetching at night to circumvent congestion resulting from flat-rated pricing). To avoid waste, it's essential to get the prices right the first time. But that requires data about user preferences, which up to now no one has collected.... Varian says the initial data from 56 subjects over the past two months are statistically very clean and show, not surprisingly, strong correlations between price and usage levels. The question researchers hope to answer is what premium users place on greater speed, and what forms of usage-based pricing make them most comfortable.

Sprint: Pricing by the byte

On June 2, Sprint announced its Integrated On-Demand Network (ION), which will be available to businesses later this year and to residential customers in late 1999. The announcement was both revolutionary and uninspiring. On the revolutionary side, Sprint is the first incumbent facilities-based carrier to announce a major "data-centric" network overhaul. Sprint says it has spent \$2 billion over the past five years quietly upgrading its network to handle data traffic more efficiently. On the uninspiring side, Sprint is building ION around ATM, the traditional telco convergence technology, rather than engaging in a more revolutionary reorientation of its network. For residential customers and businesses outside urban centers, Sprint will still have to gain access to customers through local loops controlled by local phone companies (see Appendix, page 24).

The major selling point for Sprint is that it will be able to transport voice and data services, and multiple voice lines, over a single wire. Sprint claims its architecture will reduce the cost of a long-distance call by 70 percent, although Sprint has given no indication that it plans to drop its dime-a-minute long-distance pricing to 3 cents.

An interesting aspect of the Sprint announcement is the pricing model. Sprint will provide metering devices to end-users, at a cost of approximately \$200. These boxes will track the bandwidth that subscribers use, and Sprint will bill based on bandwidth usage rather than minutes. The question is whether users will appreciate this mechanism. Bandwidth makes more sense than minutes for data traffic, because merely being connected does not generate any incremental costs for the network. However, users accustomed to unlimited pricing may balk at any usage charges.

BANDWIDTH TRADING

Eventually, markets rather than providers will set most communications prices. The subversive reality of capitalism is that the right price really is no more than what someone will pay. (Karl Marx called this decoupling of prices and underlying value commodity fetishism). That's why a PC that costs \$2,000 today might be worth \$500 a year from now, even though the machine itself hasn't changed.

Companies in competitive markets search out price points that users will accept, and then tailor their products to reach those price points. The tradition in non-competitive markets such as telecommunications has been the opposite: Regulators figure out what something "costs" and then assign a price based on a markup factor reflecting the provider's "rate of return." Costs certainly influence prices, and network architectures certainly influence costs. But the relationships aren't linear. Companies may take different levels of risk, or may structure their business models differently: Microsoft gave away its browser not because it had found a cheaper way to develop software than Netscape. Some markets, such as the retail ISP industry in the US, converge around a default price, leaving service providers to compete on features and brand. Others separate out into multiple price points for different classes of customers.

The key factor is the existence of a competitive market. In such a market, any price is presumably reasonable, because companies that set prices too high or too low are disciplined by the invisible hand. Without a market, all prices are presumably artificial. The retail bandwidth market is still not competitive for most end-users. Despite competition among service providers, incumbent telephone companies continue to provide the vast majority of local connections. Over time, competitive and technological developments will undermine this control. When the dust settles, though, how will prices be set?

At the wholesale level, two companies have established exchanges for carriers to trade capacity, and several competitors are in the works.

Band-X

Band-X, a London-based company launched in July 1997, was the first to establish a functioning bandwidth exchange. The company, founded by Marcus de Ferranti and Richard Elliot, now has over 2,400 registered users on its Web-based trading system. De Ferranti, who previously worked on telecommunications deregulation issues for the British government, says that the Internet enables a new generation of virtual markets, making information instantly available anywhere in the world. Global telecommunications deregulation has also helped, creating fragmented markets with many players looking to buy capacity.

Band-X's screens display available bids and offers on particular routes, without listing the names of the companies placing them. When a user wishes to engage in a transaction, he or she calls Band-X which introduces the potential buyer and seller. The two parties negotiate a deal, and if they reach agreement they pay Band-X a 0.625 percent commission. De Ferranti fully expects Band-X to evolve to a real-time market, and Band-X is developing plans to enable immediate clearing of transactions. The comp-

any, which still consists of de Ferranti, Elliot, and two part-time staff, plans to add another person every two months to keep up with growth.

Major carriers almost never publish their wholesale rates. Many have joined Band-X simply to gain information about price trends, even if they do not yet engage in active transactions. The Band-X indices, showing price movements on the top 20 routes out of London and New York, are now available through several publications and financial news services as well as on the Band-X Website. Carriers provide their rates to Band-X on confidential basis, in exchange for a private summary showing how they compare to the norm. Band-X computes averages and then publishes indices that show only relative price trends. Elliot comes from a financial background, and Band-X consciously designed the indices to facilitate trading in derivatives such as options and futures. The spot market isn't yet sufficiently liquid for such secondary markets to emerge, but de Ferranti fully expects them to. He points out that derivatives account for 20 times the volume of direct spot markets in commodities such as oil.

De Ferranti believes that in the next few years wholesale telecommunications prices will fall "through the floor" as Band-X fosters and benefits from a fluid market. In just the last few months, a trans-Atlantic El circuit as posted on Band-X with a two-year commitment has fallen from \$30,000 to \$6,000. Interestingly enough, many carriers have recently purchased more international capacity than they really need, because they can depreciate the costs over the 25-year length of traditional Indefeasible Right of Use (IRU) agreements. With telecommunications stocks frequently valued based on earnings before interest, taxes, depreciation and amortization (EBITDA), this trick provides an artificial boost to the bottom line that often bumps up stock prices. On the other hand, the result is that many carriers have excess bandwidth, which they are willing to sell at reduced rates through mechanisms such as Band-X.

RateXchange

Former Sprint and MFS executive Sean Whelan says he founded RateXchange, a San Francisco-based competitor to Band-X, because he too saw an oversupply of wholesale capacity emerging. The growth in backbone bandwidth, Whelan feels, will cause carriers to think differently about how they sell capacity on their networks. He thinks carriers will focus on the opportunity cost of unused bandwidth, along the lines of the airline industry, rather than simply looking to recoup their investments. To get there, however, "somebody needs to lead the way," which is where RateXchange fits in.

RateXchange, which consists of Whelan and two other people, was launched on January 5. Although Band-X was first to market, Whelan sees room for multiple exchanges, with the real competition being the traditional bilateral methods of buying and selling capacity. RateXchange currently has about 500 carrier and corporate registrants, with 10 to 20 more joining each day. Some 450 bids and offers have been posted, leading to over 40 transactions. (Like Band-X, RateXchange simply introduces parties and takes a commission if they reach agreement.)

Offers on RateXchange are divided into four service grades: facilities-based carriers selling their own capacity; resale carriers; bypass circuits (not terminating on the public network); and Internet telephony. Eventu-

ally, Whelan sees more standardized performance benchmarks emerging, using the same metrics that carriers employ today to test out new routes. As the quality of Internet telephony improves, Whelan believes it will eventually comprise the majority of transactions on RateXchange. Whelan agrees with Band-X that derivatives markets will emerge to reduce risk and improve liquidity, but believes such developments are three to five years away.

What's missing

The current generation of bandwidth markets is limited. Band-X and RateXchange do not yet provide fully anonymous transactions. One reason for this limitation is the absence of sufficient trust. Traders in established markets such as the New York Stock Exchange trust that their transactions will be executed properly and fairly. Some of this trust comes from the "backstop" of government regulation through the Securities and Exchange Commission. It will be interesting to see whether such existing financial regulators will be necessary or sufficient to generate sufficient confidence in bandwidth markets. On the one hand, these markets may be able to develop without comprehensive regulation, because they serve knowledgeable players and the exchanges themselves can take steps to reassure their customers (similar to lightly-regulated hedge funds). On the other hand, new regulatory bodies – national, international or otherwise – may develop to police the new animals of bandwidth markets.

Another reason anonymous bandwidth transactions are not yet available is that no one is quite sure what bandwidth means. There are several quality of service variables involved, as well as differing protocols. For bandwidth to function as a true commodity, there must be standards for how bandwidth can be measured and provided. For voice traffic, companies such as AT&T have developed technologies to "listen" to a line in order to ascertain sound quality on a standard scale. Similarly precise standards for data traffic are possible, if the relevant parties can agree on them.

In the voice world, private and governmental organizations such as Bellcore and the ITU have long overseen technical standards to ensure interoperability. Several efforts are underway to create common frameworks in the data world and for Internet telephony. IOPS.ORG, a consortium of major Internet service providers, has been working to improve inter-provider communications in the event of outages. Internet telephony analyst Jeff Pulver recently created a memorandum of understanding process for Internet telephony providers to develop a common call detail record for billing purposes. As with many Internet issues, these are examples of self-governance through novel authority structures that compete with traditional governments for legitimacy.

VIRTUAL INFRASTRUCTURES

The death of the independent ISP has been widely proclaimed, but the number of ISPs and backbone providers continues to increase. Large national services cannot offer the same level of personal contact and customer support as small ISPs, and thanks to rapid growth they often do not provide the same level of performance. The result is an inverted bell curve distribution, with the big ISPs getting bigger at the same time as small providers continue to thrive. So long as the pie keeps getting bigger, there is room for both models.

The challenge for all but the largest ISPs is differentiation. Smaller providers must give consumers some reason to choose them over AOL, especially as transmission becomes commoditized. These smaller companies are therefore exploring content bundling, Internet telephony, content filtering, spam blocking and other value-added services to set them apart.

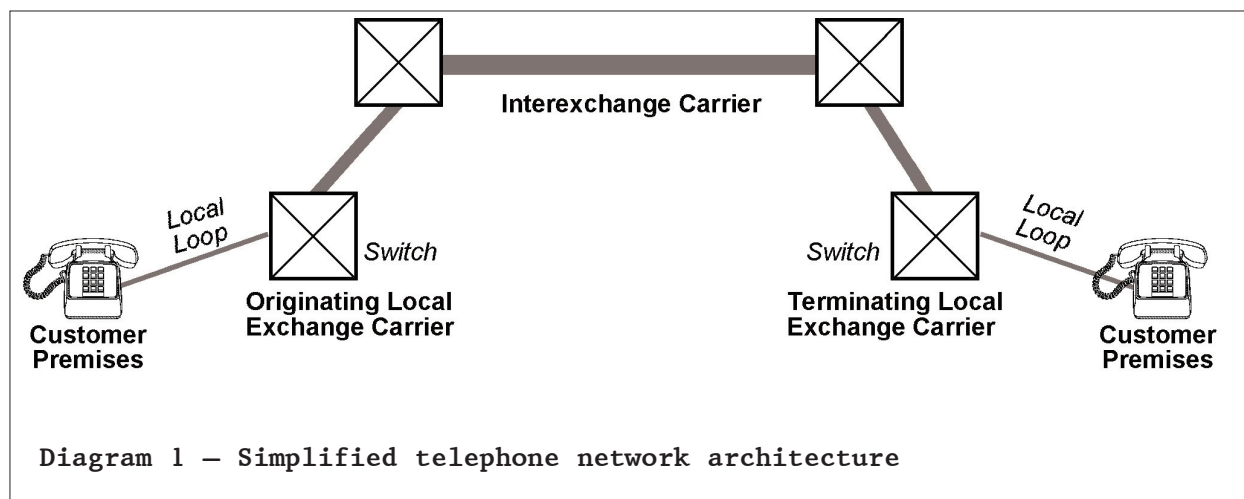
Smaller ISPs can also take advantage of the layered architecture of the Internet to avail themselves of many of the benefits that larger ISPs enjoy. An ISP is comprised of three components: Network operation, customer interaction and application servers. Only the first of these requires local infrastructure. Conventional wisdom has held for some time that Internet access was fundamentally a network business, and would therefore come to be controlled by telcos. On the other hand, companies such as Mindspring and Earthlink have demonstrated that an ISP need not own facilities to be successful. Many of the core ISP functions (such as mail and Web hosting) are now available from Web-based providers such as GeoCities and Microsoft's Hotmail. Roaming services allow local ISPs to offer global access points to their customers as a value-added feature, without the need for additional infrastructure investment.

Virtual infrastructures are emerging on top of physical networks (see **Release 1.0**, 12-95). The layered architecture of the Internet allows similar services to be provided at different levels of the protocol stack. Internet telephony imitates a low-level pure transmission service over high-level protocols in order to leverage network economies and avoid regulatory constraints. Connectivity and applications need not be tied to the same provider; users can assemble "virtual ISPs" using piece-parts from many different companies. Companies are also bundling Internet access with other product and services, such as PCs. With VPNs, users can securely connect to corporate intranets from remote sites, blurring the line between the public Internet and private networks.

The emergence of virtual infrastructures has so far had little effect on the price of connectivity. Most ISP costs are tied to hardware and phone lines, which remain the same regardless of the additional services ISPs provide. As we've seen throughout this issue, the many factors driving pricing and service quality don't lend themselves to easy generalizations.

APPENDIX: THE ECONOMICS OF BANDWIDTH TODAY

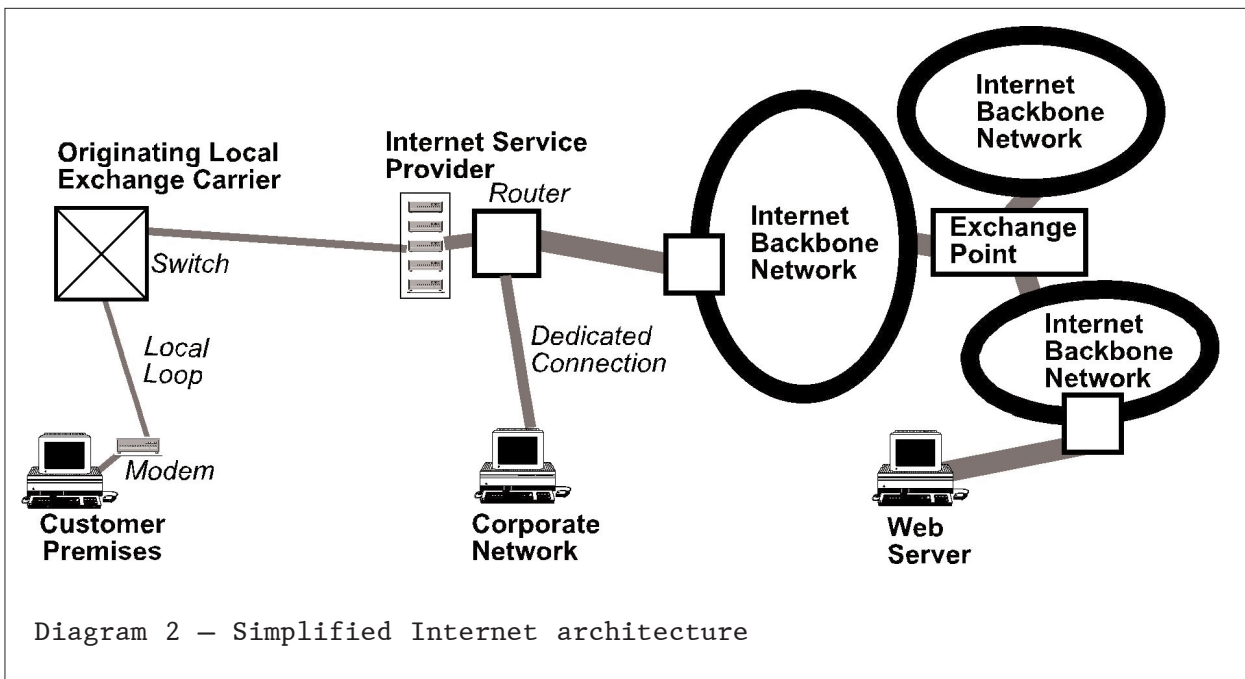
Virtually all Internet traffic today runs over local access and long-haul networks of telephone companies. (See Release 1.0, 12-95 and 11-93, for earlier discussions of the economics of connectivity.) A telephone call involves five distinct segments: Originating customer premises, originating local access, interoffice transport, terminating local access, and terminating customer premises. In the US and most other countries, the phones and inside wiring that make up the customer premises segments belong to the customer. Local loop costs vary widely with density, but not with usage, because the entire loop is dedicated to a particular customer. Switch costs and some interoffice facilities, however, are shared across multiple customers, and therefore one person's usage constrains the capacity available to others.



The Internet rides on top of this telephone infrastructure. To the telco, ISPs are simply customers that receive large numbers of calls, and that lease significant volumes of private line capacity from local and long-distance companies.

ISP networks are technically different from telephone networks. Traditional telecommunications networks employ circuit switching. In other words, the network holds open an end-to-end channel for the duration of each call. Digital circuit-switched networks employ time-division multiplexing to carry multiple calls over the same facilities; every call has a dedicated set of time slices. The Internet uses packet switching, routing packets independently through multiple network paths.

Money flows into ISPs in much the same way as it flows into local phone companies. Users pay a monthly fee for access. However, an Internet connection does not have a single end-point, and packets may be routed across multiple ISP networks to reach various destinations. Consequently, ISPs must interconnect with each other, but it makes little sense to talk about a terminating access charge in the Internet context. Backbone providers charge downstream ISPs to transport their traffic across the Internet, and these backbone providers have traditionally connected to each other on the basis of “peering” (no settlement payments). As discussed above (see page 11), the question of who gets to peer has become increasingly contentious.



The bottleneck to faster (and cheaper) Internet access tends to be the local switch. On one side is the local loop, which is dedicated to a single user and is capable of delivering significant bandwidth through digital subscriber line technology. On the other side is the digital interoffice network, comprised of high-speed fiber-optic links. In the middle, however, is a big, complex, expensive circuit switch, optimized for voice calling patterns.

Switch engineers, using decades of data, assume that an average call lasts about three minutes, and that an average retail user makes three calls in the busiest hour of the day. In most countries, customers are charged by the minute for local calls, so they tend to limit their phone and Internet usage (and if they do not, they generate additional revenue for the phone company). In the US, however, unmetered local service is the norm, and the average dial-up Internet session lasts more than 20 minutes. Local phone companies have had to spend hundreds of millions of dollars since 1996 to overcome switch congestion resulting from skyrocketing dial-up Internet usage. Most of this money has gone to purchase more conventional circuit-switching equipment, and thus has not addressed the core architectural problem of a network designed for voice being used by data.

Effects of regulation

Telephone companies have long been regulated monopolies virtually everywhere in the world. This is changing. Most members of the European Community were required to open their telecommunications markets to competition on January 1, 1998. The US has already broken up AT&T and is working towards competition in local service. Last year, 69 countries signed a World Trade Organization agreement under which they committed to liberalize their communications industries. Nonetheless, full and open competition remains the exception rather than the rule, and regulation continues to have a powerful effect on prices.

Traditional telecommunications regulation emphasizes categories. Regulators divide traffic geographically (local, long-distance, international), functionally (voice, data, video) and technologically (wireline, wireless, satellite). Different pricing structures apply to each of these categories, and in many cases different regulators have jurisdiction over different categories. In the US, the FCC sets interstate rates, but state public utility commissions set local rates. In the UK, the Office of Telecommunications (OfTel) regulates local and long-distance telephony, but has no jurisdiction over broadcasting. And so forth.

Lost in this maze of categories is a simple reality – the justification for traditional categories has been eroding for some time. Many of the existing divisions are arbitrary; we have sharp divisions between local and long-distance service in the US because of the corporate structure of pre-divestiture AT&T and the manner in which AT&T was broken up. Other aspects of the status quo, like pricing based on minutes of use, were tied to then-prevalent network architectures. In a circuit-switched network, a switch can carry a limited number of calls but each call gets a full transmission path. Consequently, it makes sense to price by minute – longer calls tie up switch ports and require additional capacity to handle other calls. But packet switches work differently. The limiting factor on packet-switched networks is bandwidth, because no capacity is dedicated to an individual call. Packet-switched networks are “always-on,” and so the only relevant metric is the amount of data being sent.

Regulation and monopoly have long inflated both costs and prices in communications. In the US, “universal service” began as an AT&T marketing slogan to support the emergence of one dominant carrier, but evolved into a complex subsidy mechanism to reduce the price of local calls, especially in rural areas. Local phone companies in the US collect more than \$20 billion per year in “access charges” for originating and terminating long-distance calls, even though their costs are only a fraction of that amount. These charges have been understood to subsidize local service in high-cost areas, but because the subsidies are implicit it becomes impossible to disentangle what is real and what is artificial. Similar mechanisms are used elsewhere in the world to subsidize governments and particular classes of calls. Internet telephony terrifies incumbents because it avoids many of these regulatory games.

For international calls, carriers impose “settlement charges” to terminate in their countries. These often-exorbitant charges subsidize either domestic phone service in those countries or other government projects. Service providers look to avoid these rates by routing traffic through third countries, or by using callback services to reverse the direction of a call. One consequence, however, is that far more traffic now originates in the US (where outbound international calling is relatively cheap) than elsewhere. US carriers now pay roughly \$5.5 billion in net annual settlement charges to foreign carriers, which has led the FCC to take aggressive steps to force countries to lower their rates.

Similar patterns exist for Internet traffic: For example, OECD statistics show that 46.7 percent of Singapore’s global Internet connectivity is routed via Vancouver, Canada. Because the Internet originally developed in the US, and the most popular sites still reside there, service providers in other countries generally must pay to bring their traffic to exchange

points in the US. Telstra of Australia and KDD of Japan have sued the FCC for allowing this practice, arguing that international circuit costs should be split equally. The reality, however, is that the imbalance of traffic is due largely to the high price of bandwidth in many countries and the absence of local exchange points, both of which will change over time.

Why competition matters...

Incumbent telephone companies will not reduce their prices dramatically unless they face pressure from competitors. Despite the costs of switch congestion, the Internet has so far been a tremendous boon to local phone companies. Second phone lines, which are especially lucrative because they usually do not require additional infrastructure deployment, are now used in over 15 percent of US homes in large part due to modem usage. Corporate and ISP demand for dedicated data circuits has skyrocketed, representing a \$5 to \$10 billion annual business in the US. The cost of deploying a T1 circuit has dropped significantly thanks to high-speed digital subscriber line (HDSL) technology in the phone network, but prices have remained steady, leading to increased profit margins. Prices are even higher outside the US, where competition tends to be even more limited.

The high prices for data circuits today create a barrier to deployment of broadband technologies. A phone company that can sell a 1.544 mbps T1 circuit for \$1,000 per month will think twice about offering similar capacity to users through asymmetric digital subscriber line (ADSL) at \$50 or \$100 per month. Incumbents won't cannibalize their own services until they become convinced that someone else will eat them first.

...and why it's hard

The inefficiencies of the current local-access infrastructure have been clear for some time. Yet for all the talk of convergence and competition little has changed. Opening up or circumventing the local loop turns out to be very difficult. In the US, the Telecommunications Act of 1996 requires incumbent local exchange carriers (ILECs) to provide competitors with access to their network at any reasonable point. For competitive local exchange carriers (CLECs) and independent ISPs to offer DSL services, they must gain access to "unbundled loops" between subscribers and the incumbents' central offices. Pricing these unbundled loops and provisioning them, however, turns out to be very tricky. A federal court in St. Louis struck down the FCC's national pricing guidelines on the grounds that only state public utility commissions can set prices for local facilities, leading to contentious battles in every state.

About 20 small ISPs have recently advocated an alternate approach to the FCC. Rather than seeking unbundled access to incumbent networks, these ISPs have requested access to "unswitched clean copper" as a retail service. Common carriers such as the ILECs are required to provide services to customers upon reasonable request. The ISPs and their attorney, Chris Savage of Cole, Raywid and Braverman, argue that ILECs themselves could provide "data-ready" copper loops to ISPs and their customers, so that these end-users could attach DSL equipment and bypass local switches. The FCC has not yet acted on this request, but it provides an intriguing alternative worth trying.

A hopeful note?

Slowly but surely local-access bandwidth bottlenecks are being overcome. Some 200,000 US subscribers use high-speed cable modems, and all of the Bell Operating Companies have announced plans to deploy ADSL within the next nine months. Similar services are being rolled out in Canada, Europe and Asia. Other broadband technologies including local multipoint distribution service wireless, access via satellite and data over electric power lines are in trials around the world. Even if the incumbents do not move quickly, others will find ways to respond to the pent-up demand for bandwidth. Whatever the future of communications looks like, we can be sure it will be different from the past.

COMING SOON

- *The Net and small businesses.*
- *Audience behavior measurement.*
- *Home-based local area networks.*
- *And much more... (If you know of any good examples of the categories listed above, please let us know.)*

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RESOURCES & PHONE NUMBERS

Marcus de Ferranti, **Band-X**, +44 (171) 341-9628; fax, +44 (171) 244-8103;
mdef@band-x.com

Christian Huitema, **Bellcore**, (201) 829-4266; fax, (201) 829-2504;
huitema@bellcore.com

Bob Moscovitz, **Chrysler**, (801) 758-8212; rgm3@chrysler.com

Gilad Zlotkin, **CLASS Data Systems**, +972 (9) 746-2020; fax, +972 (9) 746-2021; gilad@classdata.com; www.classdata.com

Chris Savage, **Cole, Raywid & Braverman**, (202) 659-9750; fax, (202) 452-0067;
csavage@crblaw.com; www.crblaw.com

Eli Noam, **Columbia University**, (212) 854-4222; fax (212) 932-7816; enoam@research.gsb.columbia.edu; www.citi.columbia.edu

Neil Tagare, **CTR Group**, (201) 505-9000; fax, (201) 505-9033; tagare@oxygen.org; www.oxygen.org

David Tennenhouse, **DARPA**, (703) 696-2263; fax, (703) 696-2202;
dtennenhouse@darpa.mil; www.darpa.mil

Sean Donnelean, **Data Research Associates**, (314) 432-1100; fax, (314) 993-8927; sean@sdg.dra.com; www.dra.com

Ron Higgins, **Digital Island**, (808) 540-4000; fax, (808) 540-4040; www.dig-isle.net

Frances Cairncross, **The Economist**, +44 (171) 830-7025; fax, +44 (171) 839-2968

Edward Gordon, **Inktomi**, +44 (137) 274-1212; fax, +44 (137) 274-1215;
egordon@inktomi.com

Randall Pigott, **InterCache**, (800) 401-6380; fax, (800) 356-0968

Anthony Naughtin, **InterNAP**, (206) 441-8800; fax, (206) 256-9580; tony@internap.com

Ira Richer, **IOPS.ORG**, (617) 621-7152; richer@cnri.reston.va.us; www.iops.org

Phillip Mutooni, **IP Phusion**, (617) 621-7008; fax, (617) 621-7022

Shai Herzog, **IPHighway**, (408) 390-3045; fax, (408) 490-2886;
herzog@iphighway.com

David Isenberg, **Isen.com**, (908) 654-0772; isen@isen.com; www.isen.com

Sverker Lindbo, **Mirror Image**, +46 (8) 506-255-20; fax, +46 (8) 506-255-01;
sverker@mirror-image.com; www.mirror-image.com

Vint Cerf, **MCI**, (703) 620-8990; vcerf@mci.net

Charles Ferguson, **MIT**, (415) 928-4139; chf@cferguson.com

Sam Paltridge, **OECD**, +33 (14) 524-9379; fax, +33 (14) 524-9332; sam.paltridge@oecd.org; www.oecd.org

Charles Muirhead, **Orchestream**, +44 (171) 460-4460; fax, +44 (171) 460-4461;
cmuirhead@orchestream.com

Jeff Pulver, **Pulver.com**, (516) 487-1424; fax, (516) 487-7269;
jeff@pulver.com

Sean Whelan, **RateXchange**, (415) 550-2600; sean@ratexchange.com

Mike Gaddis, **Savvis**, (314) 727-5596; fax, (314) 719-2499

Doug Humphrey, **Doug Mohny, SkyCache**, (301) 598-0500; fax, (301) 598-0837;
moo@skycache.com

Sydney Shaw, **Sprint**, (202) 828-7428; sydney.shaw@mail.sprint.com

Greg Staple, **Telegeography**, (202) 467-0845; fax, (202) 467-0851; greg.staple@koteen.com

Hal Varian, **University of California at Berkeley**, (510) 642-9980;
hal@sims.berkeley.edu; sims.berkeley.edu

Mike O'Dell, **UUNET**, (703) 206-5890; mo@uu.net; www.uu.net

RELEASE 1.0 CALENDAR

1998

- June 23-24 ***Department of Commerce Public Meeting on Internet Privacy** - Washington, DC. Dialogue, roundtables and working sessions with all the major players. E-mail Jane Coffin, privacy@ntia.doc.gov; www.ntia.doc.gov/ntiahome/privacy/.
- June 24-26 ***WITI: Technology Summit '98** - Santa Clara, CA. Organized by Women in Technology International. With Esther Dyson. Call (800) 334-9484 or (818) 990-6705; fax, (818) 906-3299; conference-info@witi.org.
- July 19-21 **#Spotlight '98** - Laguna Niguel, CA. Sponsored by IDG. Michael Schrage hosts discussions on new business models for media and technology. With Barry Diller, Joe Nacchio and David Dorman. Call (800) 633-4312; fax, (650) 286-2750; conference_registrar@idg.com.
- July 19-22 **ISA Summit '98** - Los Angeles. Sponsored by Interactive Services Association. Call (301) 495-4955; fax, (301) 495-4959; isa@isa.net.
- July 20-24 ***INET '98** - Geneva. Sponsored by the Internet Society. Over 3000 expected. Call Mark Measday, +41 (22) 344-64-64; fax +41 (22) 345-92-58; measday@josmarian.ch.
- July 22-25 **Third Annual Genetic Programming Conference** - Madison, WI. Automatic programming techniques for evolving computer programs. Contact John Koza, (650) 328-3123; fax, (650) 321-4457; koza@cs.stanford.edu.
- July 26-30 **Fifteenth National Conference on Artificial Intelligence** - Madison, WI. Sponsored by AAAI. Write Charles Rich, rich@merl.com.
- September 14-17 **Voice on the Net Fall 1998** - Washington, DC. Internet telephony and related technologies. Produced by Pulver.com. For information call (516) 753-2640; fax, (516) 293-3996; e-mail von98@pulver.com.
- October 11-13 ****EDventure's High-Tech Forum** - Copenhagen, Denmark. Sponsored by EDventure Holdings. Call Daphne Kis, (212) 924-8800; fax, (212) 924-0240; daphne@edventure.com; www.edventure.com.
- November 4-6 **Human Resource Technology Conference and Exposition** - Philadelphia, PA. Latest on knowledge management and corporate intranets. Sponsored by L.R.P. Call (800) 727-1227; fax, (703) 739-0489; lrpconf@lrp.com/ More information at www.lrp.com/Conferences/conferences.htm.

** Events Esther plans to attend.*

Events Kevin plans to attend.

Lack of a symbol is no indication of lack of merit.

The full, current calendar is available on our Website (www.edventure.com). Please let us know about other events we should include. - Mari Katsunuma

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